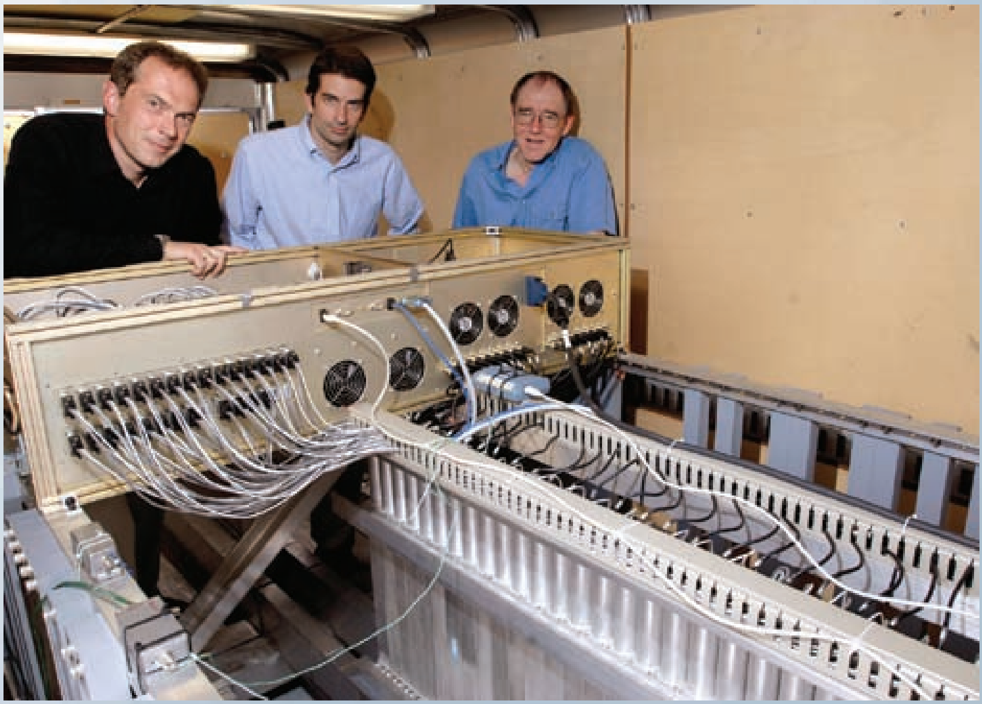
Mobile Mapping for Radioactive Materials

AS part of Livermore's national security mission, Laboratory researchers are applying their expertise in radiation sensing to develop technologies that can detect and intercept stolen nuclear materials. One recent success is the large-area imager (LAI), which uses gamma-ray imaging to pinpoint the source of radioactivity. (See *S&TR*, May 2006, pp. 4–10.) Developed in collaboration with Oak Ridge National Laboratory and the University of California at Berkeley's Space Sciences Laboratory, LAI combines radiation detection and imaging into a compact instrument for mobile operation. The device quickly scans a sizable area and maps the radiation field with a range and accuracy unmatched by available technologies.

The research team, led by Laboratory engineer Lorenzo Fabris and physicist Klaus Ziock (both now at Oak Ridge), received an R&D 100 Award for the innovative technology. Other team members include Livermore engineers Jeff Collins, Dennis Carr, and Chris Cork; engineering technician Marianne Ammendolia, also from Livermore; and computer programmers Thomas Karnowski from Oak Ridge and Will Marchant from the Space Sciences Laboratory. The team received funding from Livermore's Laboratory Directed Research and Development Program and the Department of Homeland Security. In tests with a prototype mounted on a truck traveling 40 kilometers per hour, the imager detected a 1-millicurie sample of a cesium isotope located 50 meters away. The team completed the prototype design in July 2006, and the instrument is being commercially licensed.



The large-area imager (LAI) fits on the back of a small truck or trailer. Team members at Oak Ridge National Laboratory (from left): Lorenzo Fabris, Thomas Karnowski, and Klaus Ziock.

Locating a Radiation Source

LAI uses gamma rays to pinpoint various radiation sources—from chunks of uranium to a truck filled with bananas. Gamma rays, produced through radioactive decay, have the highest energy in the electromagnetic spectrum and thus can penetrate most materials. Because of this extreme penetrability, researchers can use gamma rays to detect radioactivity even if the radiation source is shielded by concrete, dirt, or a few centimeters of lead.

However, gamma rays can only be viewed indirectly by observing their interactions with detector materials. The intensity and energy of gamma rays emitted by a source provides clues to the type of material producing the radiation. Because gamma radiation is a high-energy type of light, it travels in straight lines from the source to the detector. Imaging gamma rays thus shows the material's location.

Background radiation levels vary from place to place. Search instruments generally detect radiation sources only at close ranges (within a few meters) or when a source is much stronger than the area's background radiation levels. Sources of modest strength cannot be detected beyond a few meters because the signal they induce in a detector may appear the same as the normal variation in radioactivity. If an instrument's sensitivity were adjusted to account for these fluctuations, naturally occurring radioisotopes emitted by harmless materials would falsely appear

The LAI development team at Livermore (from left): Dennis Carr, Marianne Ammendolia, and Jeff Collins. Not pictured: Chris Cork.

as a dangerous radiation source. The similarity between hazardous and benign sources makes the detection of weak but significant signals impossible unless variations in background radiation are known in advance, which is unlikely.

Seeing through the Background

To conquer the clutter problem, the research team adapted an imaging method developed for astrophysics. In this technique, a coded aperture—a lead mask with openings arranged in a special pattern—is placed in front of a detector array. As the array picks up gamma-ray signals, the radiation incident on the mask casts shadows on the detector elements, and the imager records these patterns. The mask is designed so that each possible source location in the field of view produces a unique shadow pattern on the detector array. Processing software uses these patterns to determine the signal count and the source's location.

One disadvantage of coded-aperture imagers is that gamma-ray sources outside an instrument's viewing field can contribute to the signal count and generate artifacts in the image. To correct for this blurring effect, the team added a second imager. The mask for this imager has open and closed elements arranged in the reverse pattern of that used on the first imager's mask.

As the instrument travels through an area, it takes snapshots of the radiation field and uses them to produce a two-dimensional map showing where each source is generated. LAI's navigation system tracks the imager's location and orientation so that gamma-ray data can be superimposed on satellite images of an area.

LAI can measure gamma-ray energies from 60 to 3,000 kiloelectronvolts—the range of interest for most national security applications. The current design fits on the back of a small truck or trailer and can be used to probe neighborhoods with low-rise commercial buildings and houses. The aperture mask pairs on each side of a detector array are coded with different patterns so the imager can sample both sides of the road as the vehicle travels through an area. This design combines speed, sensitivity, and detail. LAI can sweep an area about 25 times faster than other detection technologies, dramatically reducing the time necessary to conduct a search. The device can also pinpoint a radiation source within a 5- by 5-meter area.

Homeland Security Applications

"Gamma-ray imaging is highly effective at distinguishing illicit sources from harmless background radiation," says Fabris. "We foresee this technology being adapted for various scenarios, such as scanning buildings or monitoring port and harbor entries." For example, Ziock is extending the technology to track radioactive materials in vehicles. Other applications include routine surveillance of key targets, facility inspections prior to special events, and searches based on intelligence information.

LAI is an important contribution to improving the nation's security. Accurately mapping radioactive sources will help border agents, customs inspectors, law-enforcement officers, and incident response personnel to locate illicit nuclear material.

—Rose Hansen

Key Words: coded aperture, gamma rays, large-area imager (LAI), radiation detection, R&D 100 Award.

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